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Renal Artery Aneurysms

A 35-Year Clinical Experience With 252 Aneurysms in 168 Patients

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Objective
To define the relevance of treating renal artery aneurysms (RAAs) surgically.

Summary Background Data
Most prior definitions of the clinical, pathologic, and management features of RAAs have evolved from anecdotal reports. Controversy surrounding this clinical entity continues.

Methods
A retrospective review was undertaken of 168 patients (107 women, 61 men) with 252 RAAs encountered over 35 years at the University of Michigan Hospital. Aneurysms were solitary in 115 patients and multiple in 53 patients. Bilateral RAAs occurred in 32 patients. Associated diseases included hypertension (73%), renal artery fibrodysplasia (34%), systemic atherosclerosis (25%), and extrarenal aneurysms (6.5%). Most RAAs were saccular (79%) and noncalcified (63%). The main renal artery bifurcation was the most common site of aneurysms (60%). RAAs were often asymptomatic (55%), with a diagnosis made most often during arteriographic study for suspected renovascular hypertension (42%).

Results
Surgery was performed in 121 patients (average RAA size 1.5 cm), including 14 patients undergoing unilateral repair with contralateral RAA observation. The remaining 47 patients (average RAA size 1.3 cm) were not treated surgically. Operations included aneurysmectomy and angioplastic renal artery closure or segmental renal artery reimplantation, aneurysmectomy and renal artery bypass, and planned nephrectomy for unreconstructable renal arteries or advanced parenchymal disease. Eight patients underwent unplanned nephrectomy, being considered a technical failure of surgical therapy. Dialysis-dependent renal failure occurred in one patient. There were no perioperative deaths. Late follow-up (average 91 months) was available in 145 patients (86%). All but two arterial reconstructions remained clinically patent. Secondary renal artery procedures included percutaneous angioplasty, branch embolization, graft thrombectomy, and repeat bypass for late aneurysmal change of a vein conduit. Among 40 patients with clearly documented preoperative and postoperative blood pressure measurements, 60% had a significant decline in blood pressure after surgery while taking fewer antihypertensive medications. Late RAA rupture did not occur in the nonoperative patients, but no lessening of this group's hypertension was noted.

Conclusion
Surgical therapy of RAAs in properly selected patients provides excellent long-term clinical outcomes and is often associated with decreased blood pressure.

Renal artery aneurysms (RAAs) are uncommon, occurring in approximately 0.09% of the general population.[1] Most clinicians will likely encounter this entity as an incidental finding, as more frequent magnetic resonance imaging, computed tomography, and arteriographic studies are being performed for other diseases. The clinical features and management of RAAs have generally been reported through case series depicting small numbers of patients.[2–10] Considerable controversy continues to surround the treatment of these aneurysms: specifically, what size RAA warrants surgery, when and how to repair them, how to follow those not treated surgically, and whether RAAs cause hypertension or merely are associated with elevated blood pressure remain ill-defined issues.

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Because of the lack of clarity surrounding these unresolved issues, a single-institution study of macroscopic RAAs was undertaken to define their clinical features, surgical management, and outcomes. Further, as endovascular therapy advances and becomes more common for all vascular diseases, the long-term outcome and durability of surgical treatment of RAAs needs to be documented for comparison. This study builds on a prior report of 72 patients with 94 RAAs from our institution.[1]

METHODS

A review was undertaken of 168 patients with 252 RAAs encountered at the University of Michigan over a 35-year period from 1965 to 2000. Renal artery aneurysms associated with trauma, dissections, and connective diseases such as polyarteritis nodosa were excluded from this report. Similarly, mural dilations associated with medial fibrodysplasia of the renal artery were not included in this study. Patient demographics and common vascular risk factors were assessed, including tobacco use, coronary and peripheral arterial occlusive disease, diabetes, hypercholesterolemia, and hypertension. Hypertension was defined as a blood pressure exceeding 150/90 mm Hg or current drug treatment for a prior diagnosis of hypertension. Admission or first-encounter blood pressures and the most recent follow-up blood pressures were noted. Renal function was recorded at similar time points before and after surgery. A serum creatinine level of 1.5 mg/dL or greater defined renal insufficiency. Initial RAA diagnosis was suggested or documented by plain abdominal radiographs, intravenous pyelography, computed tomography scan, arteriography for evaluation of possible renal vascular hypertension as well as other diseases, and magnetic resonance angiography. All quantitative RAA measurements were made by arteriography or directly at the time of surgery.

Surgical therapy was categorized as a RAA resection with a primary or patch angioplastic closure or segmental renal artery reimplantation; RAA resection and interposition grafting; and nephrectomy. Nephrectomy was classified further into two categories: one, planned nephrectomy for anticipated unreconstructable renal artery or arteries resulting from conditions such as overt or covert aneurysmal rupture, intraparenchymal RAA location, or irreparable renal ischemia (based on multiple areas of infarction, or diminutive cortex with evidence of absent function); and two, unplanned nephrectomy resulting from technical failures of the attempted renal artery reconstruction. Perioperative complications were assessed during the first 30 days after surgery. Death was determined through hospital and office records as well as public databases. If the patient's cause of death could not be determined, it was not assumed that the patient did not die from the aneurysm. Such patients were excluded from the long-term follow-up data analysis.

Follow-up data from existing medical records was supplemented with information obtained in many instances by telephone interviews. The latter focused on whether further renal artery interventions were performed, the patient's blood pressure status and what medication he or she was currently taking, and whether renal function was normal or whether hemodialysis was required. The study was approved by the University of Michigan Institutional Review Board (#1999–511). Statistical analysis was by paired and unpaired t test, with significance assigned at $P \leq .05$. Kaplan-Meier calculations were performed and interpreted in a similar manner.

RESULTS

The mean patient age was 51 years (range 13–78). Women outnumbered men 107 to 61. The mean gravida rate among the women was 3 (range 0–11). Associated vascular diseases and risk factors included 34% with renal artery fibrodysplasia, 25% with concomitant arteriosclerotic occlusive lesions such as peripheral vascular disease or coronary artery disease, 15% with a history of or current use of tobacco, and 6.5% with aneurysms, including those of the aorta and splenic artery. Hypertension was documented in 73% of patients with a first-encounter mean blood pressure of 155/94 mm Hg. The mean duration of hypertension in these patients was 109 months before being treated for their RAAs.

Most patients had RAAs discovered incidentally because most were asymptomatic (55%). Pain presumed related to their aneurysm affected 29 patients, and 14 patients presented with hematuria attributed to their aneurysms. Symptoms, when occurring in other patients, were less specific in relation to the presence of a RAA. Three patients presented with acute overt RAA rupture. Diagnosis was made in 42% of the patients by arteriography for suspected renovascular hypertension; 15% had RAAs defined by arteriography performed for reasons unrelated to suspected renal artery disease. An initial RAA diagnosis was suspected by plain abdominal radiographs in 14% and computed tomography scan in 10%.

The average number of RAAs per patient was 1.5. Most patients had solitary RAAs (115 patients), but 53 had multiple RAAs. Bilateral RAAs affected 32 patients. RAAs were right-sided in 60% and left-sided in 40%. The average size of RAAs subjected to surgical therapy was 1.5 cm, a size not significantly different from the unoperated RAA size of 1.3 cm ($P = .1$).

Arteriographic studies were obtained in all patients except those experiencing overt rupture. Adequate studies were available for 185 RAAs to allow accurate definition of their morphometric features. RAAs were saccular in 79%, with 21% being fusiform; the latter usually were associated with advanced renal artery medial fibrodysplasia. Calcification was evident in 69 RAAs, with the remaining 117 being noncalcified. The aneurysm location along the renal artery (Fig. 1) was classified in a manner similar to that defined by others.[1,3] Most RAAs occurred at the bifurcation of or

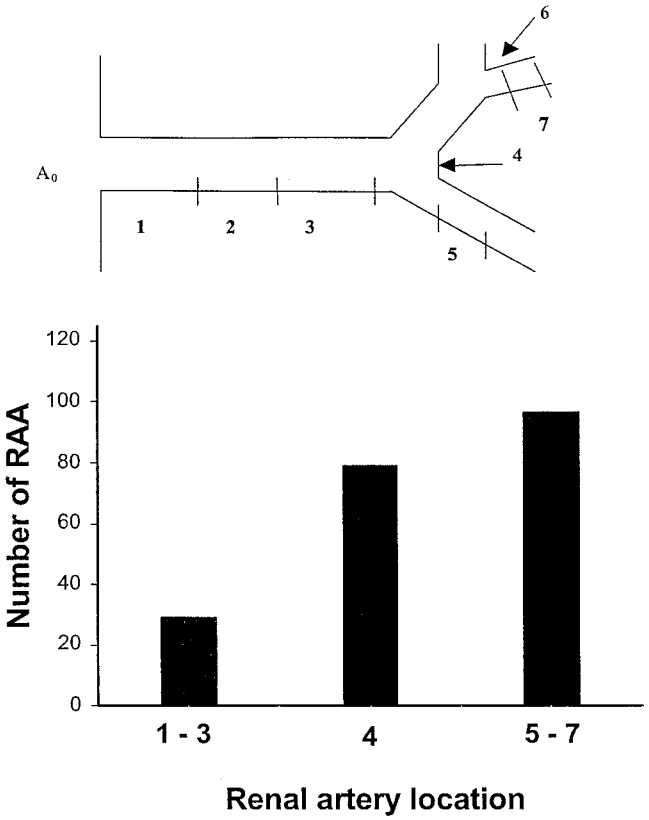

Figure 1. Location of renal artery aneurysms (RAAs) in each segmental division. Most RAAs occur at the main renal artery bifurcation.

involved the first-order renal artery branch, with the most common single location being at the main renal artery bifurcation (60%).

Surgical therapy was undertaken in 121 patients with 168 RAAs (Fig. 2). Ninety-six patients underwent renal artery reconstructions with an aneurysmectomy. Operations included aneurysmectomy and angioplastic closure of the renal artery or reimplantation of a segmental renal artery (63 patients) (Figs. 3, 4), aneurysmectomy and renal artery reconstruction with a bypass graft (33 patients) (Fig. 5), and planned nephrectomy (25 patients). Secondary nephrectomy was performed for early surgical failure after an attempted revascularization (eight patients) as a result of a nonreconstructable renal artery, early thrombosis of the repair, or excessive bleeding. There was no trend in terms of unplanned nephrectomy versus time. Late reoperations or catheter-based interventions were uncommon (seven patients). The histologic character of the excised aneurysm wall, available in 56 patients, revealed marked atherosclerotic changes (9 specimens), dysplastic changes (26 specimens), and nonspecific fibrous changes (21 specimens).

Among the 33 patients who underwent nephrectomy, there were 52 RAAs whose anatomic distribution was not significantly different from that of those undergoing an arterial reconstruction procedure or of those being simply observed without surgical intervention. Obvious conditions precluding renal revascularization included overt RAA rupture (three patients), covert RAA rupture resulting in an artery-to-vein fistula (two patients) (Fig. 6), renal cell carcinoma (two patients), and end-stage ischemic nephropathy (one patient). The average RAA size in all 33 patients undergoing nephrectomy was 1.6 cm, marginally larger than the 1.5 cm in those undergoing an arterial reconstruction ($P = .054$). However, when considering only the 25 patients undergoing a planned nephrectomy in comparison with those who underwent a revascularization procedure, there were no significant differences in RAA size or location. This suggests that factors other than anatomy may have determined the feasibility of an arterial repair in this series.

Follow-up data, averaging 91 months after surgery or the initial encounter for patients not undergoing surgery, were available in 145 patients. Outcomes in regard to combined death or graft failure rates, as depicted by life table analysis, were good (Fig. 7). Only two thrombosed grafts were documented. The mean lifespan for those with an aneurysmectomy with angioplastic closure, aneurysmectomy and bypass reconstruction, or nephrectomy was 108, 130, and 102 months, respectively, based on Kaplan-Meier estimates.

Perioperative complications included one case each of postoperative hemorrhage requiring reoperation, deep venous thrombosis, pneumonia requiring reintubation, third-degree heart block, and postoperative pancreatitis. Among 35 routine postoperative angiograms obtained before discharge, four minor technical abnormalities and one major arterial thrombosis were identified.

Among patients with an early successful repair, seven patients had later technical abnormalities recognized that required further intervention, including percutaneous anastomotic angioplasty a month or more after surgery (four patients), early reoperation for graft thrombosis during the first postoperative month (one patient), revision of a bypass venous graft for aneurysmal change 23 years after surgery (one patient), and percutaneous embolization for a stenotic segmental branch causing renovascular hypertension (one patient).

There were no deaths in the patients undergoing surgery, and only one patient had postoperative renal failure requiring hemodialysis. Late postoperative deaths from causes not involving RAA surgery or intrinsic renal disease occurred in 38 patients during the 35-year period of follow-up.

The mean preoperative blood pressure in patients undergoing surgery for RAA (excluding nephrectomies) was significantly greater than their mean postoperative blood pressure ($P < .004$), with a 94-month follow-up period in the 40 patients in whom accurate blood pressure data were available (Table 1). The postoperative serum creatinine value, available in 49 of these patients, was within the normal range. A substantial decrease in blood pressure ($\geq$15 mm Hg) occurred in 25 patients, and 13 of 24 in whom the exact number of antihypertensive medications was known had a reduction in the number of these drugs used after surgery ($P < .001$). The mode of repair, whether an aneurysmec-

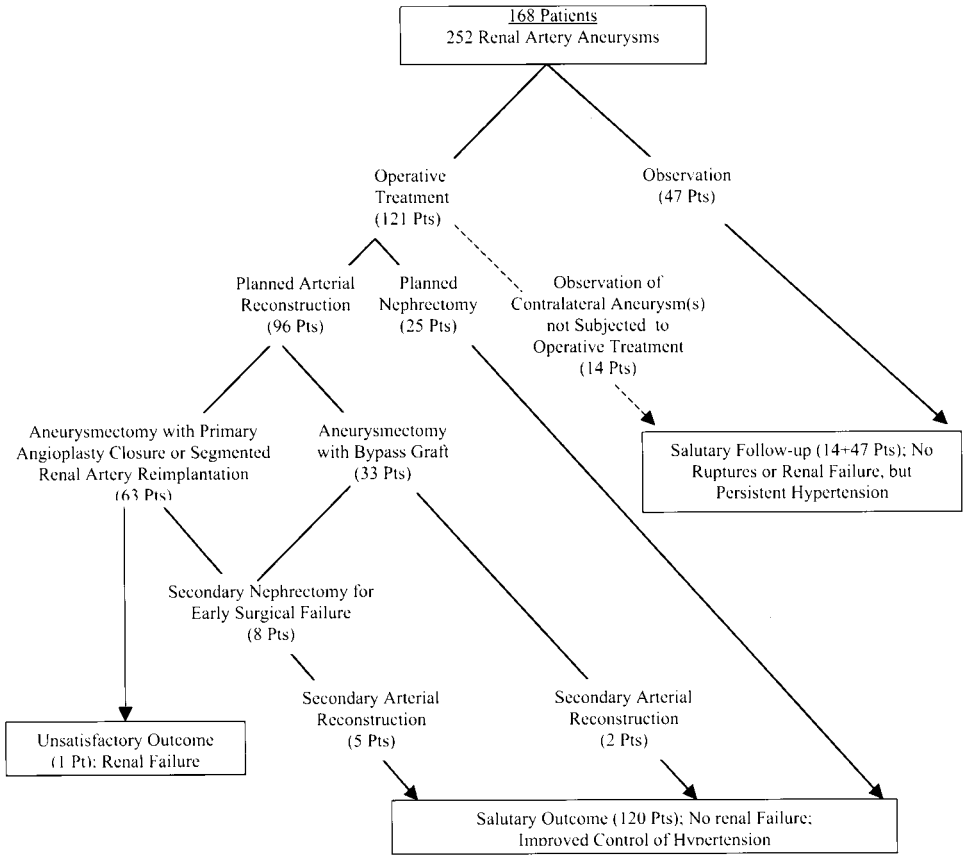

Figure 2. Clinical course of renal artery aneurysms encountered at the University of Michigan Hospital, 1965 to 2000.

tomy with angioplastic closure or a bypass, did not appear relevant in terms of hypertension: both therapeutic interventions resulted in significant reductions of blood pressure.

Of the 16 patients who underwent a nephrectomy and had preoperative and postoperative blood pressure measurements, 7 had a significant but lesser degree of blood pressure reduction compared with those undergoing arterial reconstructions, from 140/92 mm Hg to 135/78 mm Hg ($P < .05$), with an average follow-up of 102 months. However, no significant change in their antihypertensive medication regimen occurred (see Table 1). The mean serum creatinine level after surgery in the nephrectomy group was 1.25 g/dL.

Among the 14 patients with bilateral RAAs who had

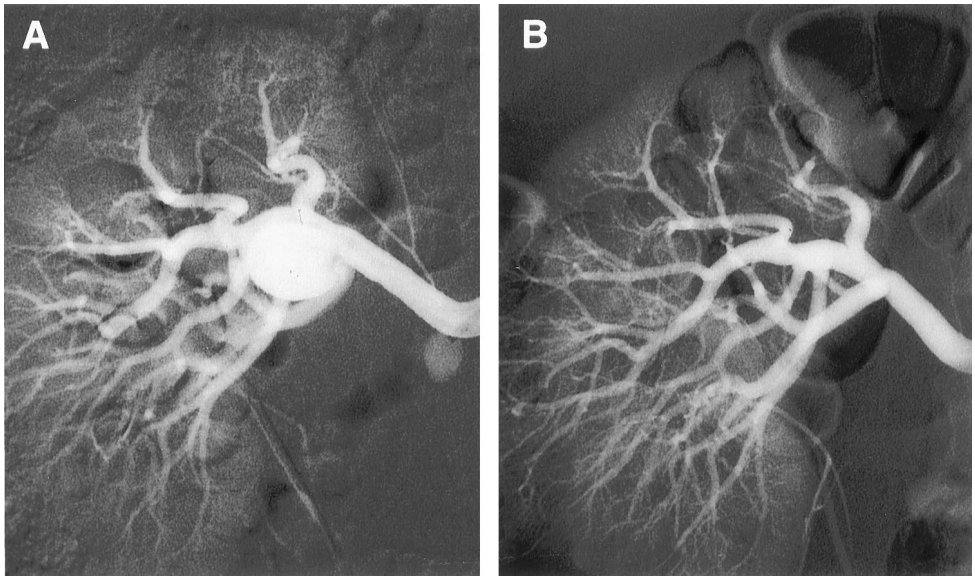

Figure 3. Aneurysmectomy and primary angioplastic closure of the renal artery. (A) Preoperative distal subtraction angiography image of a 3.0-cm renal artery aneurysm. (B) Postoperative digital subtraction angiography image showing the normal-appearing bifurcation without evidence of stenosis.

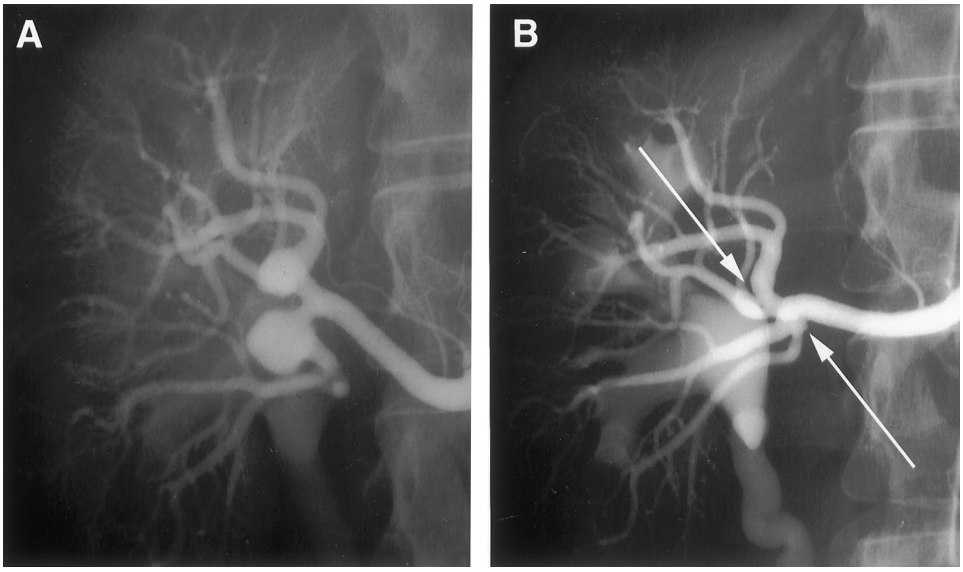

Figure 4. Renal aneurysmectomy and reimplantation of lower pole renal artery, with aneurysmectomy and angioplastic closure of upper pole renal artery. (A) Preoperative digital subtraction angiography demonstration of segment 5 and 6 renal artery aneurysms. (B) Postoperative digital subtraction angiography appearance of reimplanted lower pole artery without stenosis and normal-appearing upper pole segmental bifurcation (arrows).

unilateral repair, 11 had preoperative hypertension, and 5 of them had a significant decrease in their blood pressure after surgery, from 150/91 mm Hg to 135/75 mm Hg ($P < .001$). However, no significant reductions in the number of medications occurred in this subgroup of patients who had therapy limited to unilateral arterial reconstructions.

There were 86 RAAs subjected to observation alone in 61 patients, including the 14 patients already mentioned who underwent unilateral renal artery reconstruction without treatment of their contralateral RAAs. The mean RAA size in those observed was smaller than in the surgical group (1.3 vs. 1.5 cm), but the difference was not significant ($P > .05$). Their location within the renal artery was similar to those subjected to surgery. None of these RAAs were symptomatic. After an average follow-up of 72 months, no RAA ruptures among the nonoperative cases were documented.

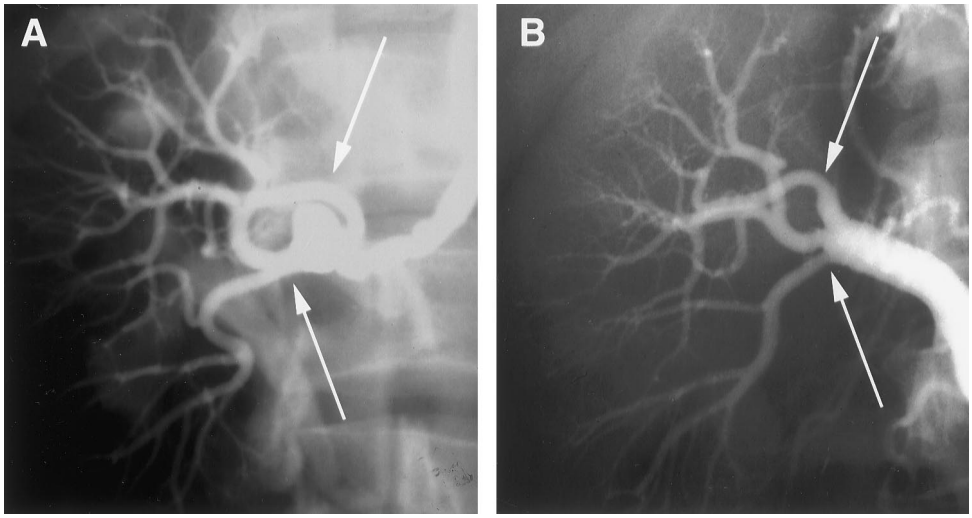

Figure 5. Renal artery aneurysm excision and bypass in a patient with fibrodysplasia of the renal artery. (A) Preoperative arteriogram documenting saccular aneurysm at the main renal artery bifurcation, with irregularities of medial fibrodysplasia evident in the proximal renal artery. (B) Postoperative image of saphenous vein bypass, with end-to-end anastomosis of the upper pole artery and end-to-side implantation of the lower pole (arrows).

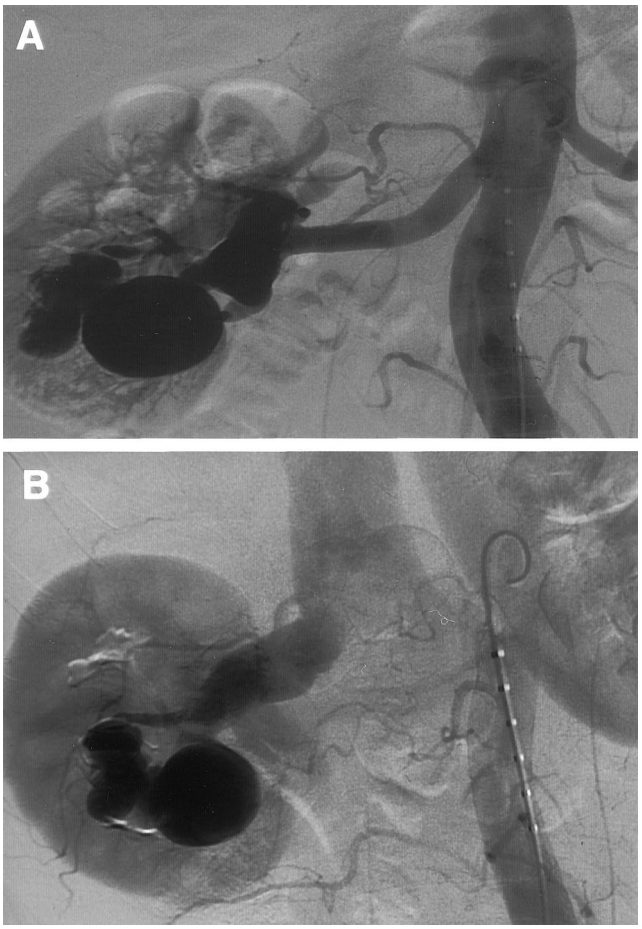

Figure 6. An unreconstructable renal artery with a complex ruptured renal artery aneurysm. A primary nephrectomy was performed with an excellent outcome. (A) Arterial phase digital subtraction angiography image of a large ruptured inferior pole renal artery aneurysm communicating with an adjacent vein. (B) Venous phase exhibiting rapid filling of the inferior vena cava with contrast.

No difference in blood pressure was noted between the first encounter and most recent follow-up at an average of 90 months (155/94 vs. 153/88 mm Hg; $P > .05$).

DISCUSSION

Renal artery aneurysms are a relatively uncommon entity whose clinical features and optimal management have not been substantiated by a large experience in the earlier literature. The present series documents the safety, efficacy, and durability of surgical therapy for RAAs. One of the most important findings of this study was the unanticipated reduction in hypertension in conjunction with fewer antihypertensive medications in patients who underwent aneurysmectomy and renal artery reconstruction. Prior reports have suggested this finding, although statistical confirmation has been lacking.[2–6,8–11] In the present series, patients with unoperated RAAs had no change in hypertension over time despite later medication changes. This supports the tenet that the efficacy of surgical repair was not simply due to a more intensive or better antihypertensive regimen during follow-up. The long-term benefits of improved hypertension control in these patients are difficult to quantify. However, this effect must be considered potentially important in that hypertensive sequelae are insidious and the complications often permanent.

Numerous theories have been put forth to explain the relation of RAAs to hypertension, including mechanical kinking or twisting of the renal artery with altered renal blood flow; embolization from the RAA to the distal parenchyma; and coexistent renal stenosis. All of these may be a cause of secondary renin-mediated hypertension. It is impossible to confirm or refute the proposition that mechanical flow alterations alone accounted for blood pressure elevations in our patients with RAAs. It would seem logical that renal artery kinking and low blood flow alterations should be related to RAA size, with larger aneurysms more likely to cause greater blood pressure elevations. However, most RAAs in this series were small ($<$2.0 cm) and a correlation of size to blood pressure elevation was not apparent. Distal thromboembolism is a possibility, but most kidneys visualized by angiography did not show distal infarction. Microembolism is another possibility, but one would expect evidence of macroscopic infarction with decreased renal function over time, and this was not observed in our patients. Other reports have suggested that hypertension in the setting of RAAs is due to concurrent renal artery stenoses.[3,8] In the present series, renal artery stenosis was documented in a few patients by angiography, and these patients underwent bypass reconstructions of the renal artery. The blood pressure response and the reduction in antihypertensive medications in this latter group of patients were similar to those undergoing aneurysmectomy and renal artery reconstruction without a bypass (see Table 1).

The population demographics of patients with RAAs are quite different than the usual patient with macroscopic aneurysms in other locations. Surprisingly, few aneurysms exhibited marked arteriosclerotic changes. Prior reports suggested that arteriosclerosis in these aneurysms is a secondary rather than a primary phenomenon.[1,3,5] Arterial fibrodysplasia, the etiology of which is not fully understood, was the most prevalent vascular disease associated with RAAs in this series. This may have accounted for the predominance of women in this experience. The underlying arterial matrix disruption known to exist in these dysplastic arteries is likely to lead to aneurysmal formation, especially at branchings where discontinuities in the internal elastic lamina are common, even in healthy persons. An unusual number of the women in this series were also multiparous. During the latter stages of gestation, an alteration in hormone and enzyme activity contributes to the normal biological processes of tissue relaxation necessary for parturition. It may be hypothesized that sustained release of these matrix-altering substances during the latter stages of pregnancy predisposes to the formation of RAAs by causing irrevers-

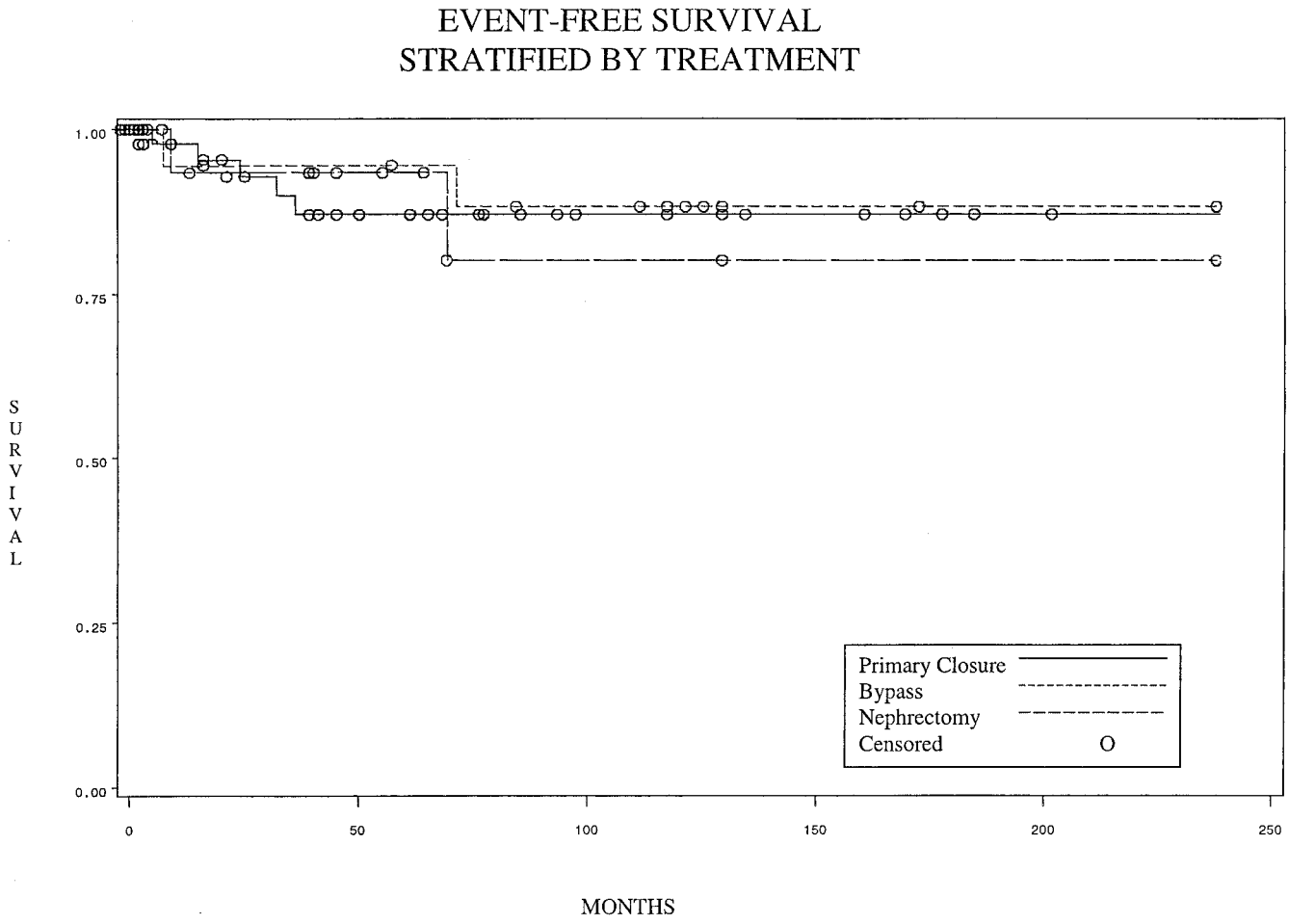

Figure 7. Life table of event-free survival in patients undergoing surgical therapy. Small dashed line represents renal artery aneurysm exclusion and bypass. Solid line represents angioplastic closure and segmental artery reimplantation. Long dashed line represents nephrectomy. No significant difference was noted between these modes of therapy in long-term event-free outcome. Beyond 250 months, only nine patients had follow-up among all groups, and comparison is not valid.

ible changes, especially in elastic tissues of arterial bifurcations, although no direct evidence of such has been forthcoming.

The decision to repair a RAA should be based on several factors, including patient age, gender, anticipated pregnancy in female patients, and the anatomic features of the RAA,

Table 1. RENAL ARTERY ANEURYSM OUTCOMES

Therapy	First Encounter or Preoperative Blood Pressure (mm Hg)	Postoperative or Most Recent Blood Pressure (mm Hg)	First Encounter or Preoperative Medication Number	Postoperative or Most Recent Medication Number
Aneurysmectomy with angioplastic reconstruction (32 pts)	150/90	139/78*†	1.9	1.0*
Aneurysmectomy with renal artery bypass (8 pts)	164/98	121/74*†	2.0	0.8*
Nephrectomy (16 pts)	140/92	135/78*†	1.6	0.9
Nonoperative (7 pts)	155/94	153/88	1.0	1.25

* $P < .01$, *t* test, vs. preoperative blood pressure or number of medications in same treatment group.
† $P < .01$, *t* test, vs. postoperative reading in nonoperative group.
Number in parentheses represents patients in whom accurate information was available regarding preoperative and postoperative blood pressures and medications.

including its size. Of these, size is the most often debated. Some suggest that no surgical therapy is necessary if the RAA is smaller than 2.0 cm.[2–9] Others have documented rupture of aneurysms smaller than 2.0 cm.[1,10,11] No significant size differences existed in our patients with nonoperated RAAs compared with those treated surgically. This suggests that most of these patients were offered surgical therapy based on presenting symptoms, uncontrolled hypertension, or a presumed risk of rupture. An isolated RAA smaller than 2 cm in a man is unlikely to rupture. However, the long-term benefit of reduced blood pressure and easier medication management of hypertension, if present in such a patient, raises the question of whether the absolute RAA size should be the deciding factor regarding surgery or nonsurgical management. Our bias is that it should not be.

Rupture of RAAs is unlikely in most patients.[12–14] Although some consider RAA calcification to be protective of rupture, no correlation between RAA calcification and risk of rupture was evident in this series or in most previous reports.[9–11] Although acute RAA rupture affected three patients in this series, none was known to have a RAA before the rupture occurred. Rupture has historically been associated with a high death rate, especially during pregnancy.[15] In nonpregnant patients, RAA rupture is likely to be associated with death in less than 10% of cases. Although all three patients experiencing RAA rupture in this series lost their kidney, none died. Anecdotal reports suggest that nephrectomy is not always a certain outcome a RAA rupture,[16] and attempts at kidney salvage in properly selected patients experiencing rupture are justified.

The relative lack of serious comorbidities in patients with RAAs accounts for the low perioperative complication rate as well as the absence of perioperative deaths in most surgical series.[1–11] However, given the technically demanding nature of surgery for RAAs, they should be treated by surgeons who have demonstrated expertise in renal artery reconstructive procedures. Even though we have considerable experience with treating RAAs, eight of our patients underwent an unplanned nephrectomy secondary to technical complications during attempted revascularization. This outcome was suboptimal. Fortunately, none of these patients suffered long-term chronic renal failure or needed hemodialysis, with an average 120-month follow-up.

Various surgical techniques for treating RAAs have been described.[1–17] We undertook in situ aneurysmectomy and revascularization in all but one of these patients. When carefully undertaken, such a direct approach carries the least risk of damage to the kidney or ureter. Excluding the most distal and complex RAAs, which might be best treated by ex vivo repairs,[2,9,17] most other RAAs are accessible for repair in situ. No major differences were noted in terms of long-term patency or need for secondary interventions between the patients who had aneurysmectomy and bypass versus those who had aneurysmectomy and primary angioplastic closure of the renal artery.

Several technical points that we consider critical to a salutary outcome warrant mention. First, all patients have a lumbar roll placed to accentuate lumbar lordosis and facilitate renal exposure. A transverse umbilical incision and transperitoneal approach is favored, with fixed retractors to aid in providing stable right or left medial visceral rotations as needed. The proximal renal artery and branches beyond the RAA are judiciously dissected free enough to be controlled with microvascular Heifetz clips. It may be necessary to mobilize the kidney from its retroperitoneal position and approach the RAA from behind when the aneurysm affects a posterior branch of the renal artery. Before interrupting renal blood flow, systemic anticoagulation with intravenous sodium heparin (150 U/kg) is established. Cooled (4°C) renal perfusate, rendered hypertonic by the addition of mannitol to lactated Ringer solution, is used in most cases to cool the kidney and reduce the risk of acute tubular necrosis. If more than 30 minutes of ischemic time is needed for the reconstruction, repeated cooling of the kidney should take place.

Certain limitations apply to this review of our experience. Despite long-term follow-up in 86% of the patients, we could not contact some patients for contemporary assessments, and poor outcomes cannot be excluded in these patients. Further, although the conclusions proposed here are well supported, this was not a prospective randomized study. It was also assumed that in patients with no further surgical procedures and good control of blood pressure, arterial reconstructions were patent. It is possible that a few of these reconstructions have failed anatomically. However, it is neither safe nor cost-justified to subject patients to yearly arteriography solely for surveillance, and it would be similarly prohibitively expensive to subject them to repeated magnetic resonance angiography for such a purpose.

Catheter-based intervention advances are increasing rapidly in all realms of vascular surgery. However, given the anatomic complexity and size and the unforgiving quality of the renal artery, it is unlikely that endovascular therapy of RAAs will become a popular or safe treatment modality in the near future. There are notable exceptions, however. Main renal artery saccular aneurysms that have a small neck have been successfully coil embolized and excluded.[18] Further, endovascular therapy has a role in the treatment of distal renal artery branch aneurysms by embolization, with the therapeutic goal of limited renal infarction with elimination of the aneurysm. This adjunct therapy was used in one patient in the current series with good results.

Our experience supports the repair of RAAs 1.0 cm or larger in patients with difficult-to-control hypertension. Other patients with incidentally discovered 1.0- to 1.5-cm RAAs without hypertension may be followed up by spiral computed tomography or magnetic resonance imaging every 1 to 2 years. Most aneurysms 1.5 to 2.0 cm and all those larger than 2.0 cm, regardless of blood pressure status, should be treated surgically if their anatomic character suggests a relatively noncomplex renal artery reconstruction and the procedure is undertaken by a surgeon experienced in

renal artery interventions. The most important indication for surgical repair appears to be the presence of concurrent hypertension and female gender, with size a relative but secondary consideration. It is impossible to say whether early surgical repair is better in the long term than aggressive medical management for RAAs smaller than 2.0 cm and hypertension until a prospective long-term study can be done. Further, whether aggressive medical management of associated hypertension will alter the natural history of RAAs remains to be determined. In patients who have had surgical repair of a RAA, postoperative imaging is recommended to detect technical problems necessitating early corrective endovascular or surgical therapy. Postoperative yearly follow-up should include blood pressure measurement and renal function determination. The durability of the salutary outcomes of surgical intervention for RAAs is excellent, and it is the standard by which other therapies should currently be judged.

Acknowledgment

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Discussion

DR. GREGORIO A. SICARD (St. Louis, Missouri): I congratulate Dr. Henke for an excellent presentation and the University of Michigan, Section of Vascular Surgery, headed by Dr. Stanley. This excellent work represents another important contribution from a group that has established the rules for managing visceral artery aneurysms.

Almost 20% of your series had bilateral renal artery aneurysms. What criteria did you use to recommend bilateral aneurysm repair versus ipsilateral repair and follow-up of the contralateral aneurysm? You have already addressed the issue of how you follow-up these patients with spiral CT scans.

About 27% of your patients underwent renal artery reconstruction. What conduit did you prefer? Your group has published previously on problems related to saphenous vein dilatation, especially in the pediatric population. Could you expand on this?

Do you think that ex-vivo reconstruction and autotransplantation could have saved some of these kidneys? Do you see any role in these very complex intra-parenchymal renal artery aneurysms for ex-vivo reconstruction?

Lastly, your series spans 35 years, during which significant advances have been made in hypertensive agents. Have you looked at the impact the new drugs might have made, especially in those patients that you are following for a renal artery aneurysm and that, as you point out, do have a slightly higher incidence of hypertension? If we follow patients medically with atherosclerotic renal artery stenosis, we see a decrease in renal mass and function. In those patients with renal artery aneurysms that you are following medically, are you seeing any effect on renal mass or renal function?

PRESENTER DR. PETER K. HENKE (Ann Arbor, Michigan): In terms of bilateral renal artery aneurysms, if the reconstruction on one side is predicted to be very complex, we will do it first, and proceed to the other side only if the repair appears secure. Otherwise we would treat bilateral lesions separately. Another criteria relates to the later blood pressure response after a unilateral repair and the size of the contralateral aneurysm. For instance, if the patient was normotensive after treatment of a renal artery aneurysm on one side, and an aneurysm smaller than 1.5 cm remained on the other side, we would opt to follow the latter without operation.

We prefer to use reversed autogenous saphenous vein for repairs requiring bypasses in adult patients. Without an adequate vein we would use a prosthetic graft. In pediatric patients, the hypogastric artery is the preferred conduit for these reconstructions. Interestingly, there was one patient in the series who did have a saphenous vein reconstruction as a child, who 27 years later had aneurysmal changes that required reoperation.

Although the nephrectomy rate in this series appears high, one should note that of the 33 patients undergoing nephrectomy, 25 were deemed to have nonreconstructable renal vessels preoperatively. Eight patients did undergo nephrectomy secondary to technical complications, and ex vivo repair might have provided a better outcome in these patients.

Antihypertensive medications have certainly improved over time, although in our patients medication types did not change that frequently. Those who benefited from operation generally were able to drop one or two types of medications. Operation had no observable effect on renal mass, although beneficial effects did accrue to blood pressure control. Over more

time, we will be able to better assess the effects of antihypertensives in the control of those patients not operated upon.

DR. LOUIS M. MESSINA (San Francisco, California): Dr. Henke and his colleagues at the University of Michigan have reported the largest series of patients who have undergone repair of renal artery aneurysms. Their zero percent mortality, low morbidity, and long-term benefits are commendable and set the standard by which all future surgical series should be judged. The majority of renal artery aneurysms will continue to be managed surgically rather than by endovascular techniques.

Finally, the vascular surgery group at the University of Michigan should be recognized for their many seminal technical contributions that have made safe and effective repair of renal artery aneurysms possible. The beneficial effect of renal artery aneurysm repair is potentially the most important contribution of this study.

My first question is whether the current availability of highly effective drug therapy for hypertension influenced their recent indications for surgical repair or the beneficial effects seen in the management of the hypertension postoperatively? Current indications for the management of renal artery occlusive disease have shifted away from control of hypertension to the management of ischemic nephropathy for this very reason.

My second question centers on the combined primary and secondary nephrectomy rate of 28%. At the University of California, San Francisco, ex vivo renal artery reconstruction, a technique developed by Folkert Belzer, M.D., has now been performed in more than 100 patients, the majority of whom had renal artery aneurysms, and the published nephrectomy rate is less than 2.5%. Again, would a wider application of ex vivo renal artery repair reduce the primary and secondary nephrectomy rates and have these rates decreased in the more recent experience?

A final comment is that because accurate blood pressure data appears to be available in less than half of the operated patients, I would favor caution in the widespread application of the recommendation that the threshold diameter for repair of renal artery definitions be reduced to 1 centimeter in hypertensive patients. I congratulate the authors on a landmark study.

DR. PETER K. HENKE: In terms of renal artery aneurysm and the beneficial effect of repair to hypertension, again, time will tell, particularly with the newer, more effective anti-hypertensive agents in some of these patients with smaller aneurysms, whether they will have the long-term benefit of reduced hypertension and a low risk of rupture.

DR. PETER K. HENKE: Nearly 5 of 6 patients undergoing primary nephrectomy, had aneurysms involving renal arteries could not have been adequately reconstructed, even with an ex vivo repair. However, in retrospect, the use of an ex vivo repair might have been a viable option in those who underwent unplanned nephrectomy. Blood pressure control with medication requires the patient to be very compliant with drug therapy throughout their life. This concern and the cost of antihypertensive agents over a lifetime might be better avoided with a single properly performed surgical procedure in a carefully selected patient.